OVERVIEW OF STREAM QUALITY ASSESSMENTS AND STREAM CLASSIFICATION IN ILLINOIS

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Abstract

Since its creation in 1970, the Illinois Environmental Protection Agency (IEPA) has relied on aquatic macroinvertebrates in biosurveys conducted to evaluate degradation from point source dischargers. Early stream surveys utilized macroinveretebrates primarily as biological water quality indicators with data interpretation and pollution assessments made on the basis of presence or absence of intolerant organisms. Current water quality assessments are made using biotic community structure, tolerance ratings assigned to invertebrate taxa on a 0 to 11 scale, and Macroinvertebrate Biotic Index (MBI) values calculated from the equation: MBI = $(n_i * t_i)/N$. More recently, biosurveys have employed fish communities as biotic tools for stream quality evaluations, use support assessments mandated by the Clean Water Act, and for a cooperative interagency Biological Stream Characterization (BSC) process. The Index of Biotic Integrity (IBI) and associated fish community metrics are the foundation of data interpretation. IBI values were calculated by a program written in BASIC for the IBM-PC. Stream habitat quality assessments are now conducted in conjunction with fish monitoring utilizing a procedure which measures depth, velocity, and substrate type at eleven equally-spaced transects. Based on an equation derived from a multiple regression of IBI values and stream habitat data, the biotic potential of streams is estimated in the form of a predicted IBI value.

Introduction

The assessment of water quality by agencies responsible for pollution abatement has historically been the domain of the engineer, chemist, and microbiologist. Early efforts relied on analysis of dissolved oxygen, biological oxygen demand, pH, suspended solids, and fecal coliform bacteria. Use of chemical analysis was well suited for the evaluation of surface water quality and compliance of point source dischargers with numerical standards as these criteria were generally chemical in nature. Pollution assessment by chemical means, however, relies on collection of representative samples from a medium known to display frequent spatiotemporal variability. Chemical samples additionally provide no information regarding the degree to which abiotic factors influence biotic community structure and function.

Rationale

Passage of the Federal Water Pollution Control Act in 1972 (PL 92-500), and most recently, the Clean Water Act (CWA) Amendments of 1987, stressed assessment of not only water chemistry, but biotic integrity of the nation's waters. Focus on assessment of biotic integrity as a means of evaluating success of pollution control programs prompted the U.S. Environmental Protection Agency (USEPA) to issue guidelines for incorporation of biotic and abiotic factors into water body assessments for water quality standards

Table 1. Metrics used to assess fish communities in Illinois streams (from Karr et al. 1986).

Category	Metric	Scoring criteria 5	3	1
Species richness and composition	1. Total number of fish species	Expectations for metrics 1-5 vary with stream size and region and are discussed in the text.		
	2. Number and identity of darter species			
	3. Number and identity of sunfish species			
	4. Number and identity of sucker species			
	5. Number and identity of intolerant species			
	6. Proportion of individuals as green sunfish	<5%	5-20%	>20%
Trophic composition	7. Proportion of individuals as omnivores	<20%	20-45%	>45%
	8. Proportion of individuals as insectivorous cyprinids	>45%	45-20%	<20%
	9. Proportion of individuals as piscivores (top carnivores)	>5%	5-1%	<1%
Fish abundance and condition	10. Number of individuals in sample	Expectations for metric 10 vary with stream size and other factors and are discussed in the text.		
	11. Proportion of individuals as hybrids	0%	>0-1%	>1%
	12. Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies	0-2%	>2-5%	>5%

evaluation (USEPA 1982) and use attainment analyses (USEPA 1983).

To accomplish mandates of the Clean Water Act, the Illinois Environmental Protection Agency (IEPA) has conducted stream quality surveys since its creation in 1970. Surveys conducted in the early seventies relied solely upon aquatic macroinvertebrates as biological water quality indicators. Since the mid-seventies, stream surveys have also included water and sediment chemistry, and in recent years, the Agency has assessed fish communities and stream habitat in small wadeable streams. This paper summarizes the current use of aquatic macroinvertebrates and fish in IEPA stream quality assessments and the Biological Stream Characterization (BSC) process, and describes the development of a habitat assessment procedure for prediction of biotic potential in lotic environments.

<u>Macroinvertebrates</u>

Aquatic macroinvertebrates as defined by Weber (1973) are invertebrates large enough to be seen by the unaided eye, can be retained by a U.S. Standard No. 30 sieve (0.595 mm), and live at least part of their life cycles within or upon available aquatic substrates. Invertebrates included in this group typically consist of annelids, macrocrustaceans, aquatic insects, and mollusks (Isom 1978). Although macroinvertebrates were not routinely used in freshwater bioassays in the past (Weber 1973), they have been extremely useful in water quality monitoring through studies of community diversity and as indicator organisms (Resh and Unzicker 1975). Some of the advantages of using macroinvertebrates for environmental impact assessments include: limited mobility; relatively long life cycles; important members of aquatic food chains; sensitivity to a wide range of contaminants; known environmental requirements for key indicator groups; ubiquitous in distribution (occur where fish may not be present); and ease of collection.

While widely used for delineation of impacts caused by putrescible wastes, macroinvertebrates have also been used as indicators of heavy-metal pollution (Winner et al 1980), bioaccumulation (Mauck and Olsen 1977), and acidification (Mills and Schinder 1986).

Use of Macroinvertebrates in Illinois -- In 1970, the Illinois Environmental Protection Agency adopted and expanded a list of indicator organisms developed by Shiffman (1953) and continued use of a classification system in which streams were classified according to the percentage of intolerant organisms present. Using this procedure, the composition of a macroinvertebrate community at balanced stations consisted of more than 50% intolerant organisms; at unbalanced sites, less than 50% but more than 10% intolerant; at semipolluted sites, less than 10% intolerant; and community structure at polluted stations consisted of 100% tolerant organisms (Tucker 1961). The merits of this system for stream quality classifications were examined by Schaeffer et al. (1985).

Collection and Identification -- In 1982 IEPA biological staff made significant revisions to the IEPA Macroinvertebrate Tolerance List, updated field collections techniques, and adopted new data interpretation procedures for wastewater impact assessments (IEPA 1987). Qualitative collections of macroinvertebrates are made in the field using a No. 30-mesh sieve, D-frame net, and/or by hand picking of available substrates. Following collection of a sample, macroinvertebrate specimens are identified to a level consistent with survey objectives. In screening level surveys conducted to document impacts from wastewater facilities, invertebrates are identified in the field to family level. In selected special surveys or cooperative basin surveys conducted with the Illinois Department of Conservation (IDOC), macroinvertebrates are identified to the taxon and/or taxonomic level which has been assigned a tolerance rating by Agency biologists (Appendix Table A).

Data Handling -- Macroinvertebrate data are presently interpreted by an examination of community attributes: community structure, taxa richness, and use of the Macroinvertebrate Biotic Index (MBI). This index is a modification of a biotic index developed in Wisconsin (Hilsenhoff 1977, 1982). The MBI, similar to the Wisconsin index, provides a summation or average of tolerance values assigned to each taxon collected and weighted by abundance; low values indicate good water quality and high values degraded water quality. This index is on a 0 to 11 scale rather than the 0 to 5 scale originally proposed by Hilsenhoff. IEPA has also assigned tolerance ratings to several invertebrate groups not rated by Hilsenhoff: Turbellaria, Annelida, Decapoda, and the Mollusca. The Macroinvertebrate

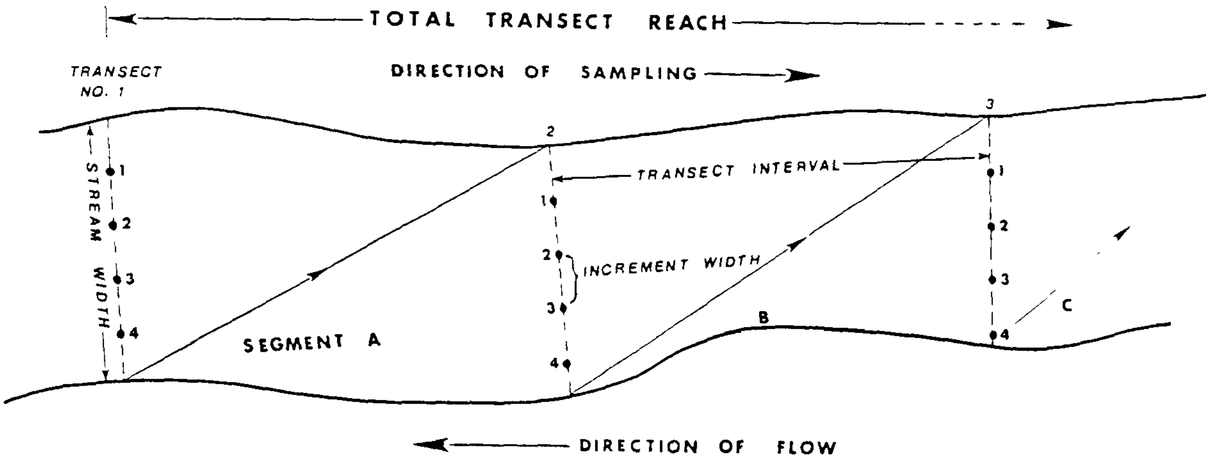

Fig. 1. Schematic diagram of IEPA habitat quality assessment procedure for wadeable streams. Sampling is initiated at the right edge of the water (REW) at transect 1. Depth, velocity and substrate measurements start at the proper increment width from REW (point 1) and sampling proceeds across transect. Additional transects are sampled at 10 yard intervals moving upstream (IEPA 1987).

Biotic Index is calculated by the following equation:

$$MBI = \sum (ni\ ti)/N$$

where: ni = No. individuals in each taxon
ti = Tolerance value for taxon
N = Total no. individuals

<u>Fish</u>

Over 180 species of fish have been recorded in Illinois (Smith 1979) and a majority of these species inhabit lotic environments. They occupy upper levels of aquatic food chains and are directly and indirectly affected by chemical and physical changes in their environment. While use of aquatic macroinvertebrates and water chemistry are integral components in the assessment of water quality and documentation of constituents causing impairment, the condition of the fishery is the most meaningful index of stream quality to the general public (Weber 1973).

Use of fish to assess biotic integrity of water resources has received increased emphasis in recent years by a number of investigators (Karr 1981; Hocutt 1981; Stauffer et al. 1976; Karr et al. 1986). Karr (1981) listed several advantages for using fish as indicator organisms in monitoring programs: life-history information is extensive for most species; fish communities generally include a range of species that represent a variety of trophic levels; fish are relatively easy to identify; both acute toxicity and stress effects can be evaluated; fish are typically present, even in the smallest streams and in all but the most polluted waters; and results of fish studies can be directly related to the fishable waters mandate of Congress.

IEPA Use of Fishery Data -- Early fish sampling efforts organized by IEPA were conducted largely to assess contaminant levels in selected fish populations in conjunction with biosurveys of Illinois river basins (Hite and King 1977). The Agency has subsequently placed greater emphasis on fish communities as indicators of stream quality. Starting in 1981, IEPA utilized fish data obtained in cooperative basin surveys by the Department of Conservation for water quality standards development, aquatic life use support assessments, stream classification, and to develop a stream habitat evaluation procedure. In 1986, the Agency initiated fish collections for the first time in an assessment of biotic integrity downstream from a large refinery complex in eastcentral Illinois (Hite et al. 1988).

Field Collection -- For stream quality assessments IEPA biologists typically collect fish with a combination of electrofishing and seining. Small wadeable streams are sampled using backpak or electroseine apparatus for 15 to 30 minutes. If additional sampling is required to obtain a representative sample, the length of sampling time is recorded for determination of catch per unit of effort. Three supplemental seine hauls with a 3/16 inch mesh seine are utilized at each site when suitable habitat exists. Larger streams are sampled using boat electrofishing gear for 30 minute periods (IEPA 1987). All fish collected are sorted, identified to species, and counted at the site. Those specimens which cannot be identified (eg., various cyprinids) are preserved in a 10 percent formalin solution for subsequent laboratory identification.

Data Interpretation -- Fisheries data are interpreted with the Index of Biotic Integrity and use of the 12 IBI metrics (Table 1; Karr et al. 1986). When fishery data does not allow calculation of a "pure" IBI value using all 12 metrics, an alternate Index of Biotic Integrity (AIBI) is calculated. Applicable metrics (e.g., number of species, intolerant individuals, etc.) of both the IBI and AIBI have been modified geographically for Illinois streams and expectations are determined by major river basin (Bertrand 1985). To expedite IBI calculations and fishery assessments made by biologists, the Agency developed a computer program for use on the IBM-PC (Kelly 1986). This program, updated in 1988 (Bickers et al. 1988), provides station location information, a summary of IBI metrics, the IBI or AIBI value (as appropriate), and a list of species collected (see Appendix Table B).

Stream Habitat Assessment

Biotic-Abiotic Relationship -- The abundance and distribution of individual species in lotic ecosystems is largely governed by geographically related physicochemical variables. Although aquatic life is found almost everywhere there is permanent water, each species has its own distribution or range; within that range, a species has unique environmental requirements and occurs in certain settings that are its habitat (Pflieger 1975).

Stream habitat consists of chemical and physical components. Both suitable water quality and desirable physical habitat (e.g., adequate depth, velocity, bottom substrate and cover) must exist to meet specific individual requirements. Both habitat components, while largely determined by geography, climate and local relief, may also be influenced by activities of man. In Illinois, few if any streams exist that have not been altered to some degree chemically or physically. These hydrological modifications, which include channelization and alteration of flow regimes, typically reduce the quality and quantity of habitat available for aquatic life, and ultimately biotic integrity. Indeed, physical alterations in the form of channelization have been reported to affect over 3400 stream miles in Illinois (Conlin 1976). In stream segments impaired by hydrological modifications, pollution control efforts to maintain and restore biotic integrity through water quality improvements may have limited success.

Instream physical habitat information was routinely recorded for all IEPA stream quality surveys in the past, but this limited data was subjective in nature. Because a systematic methodology for habitat analysis was not used in early IEPA stream surveys, it was often difficult to determine which habitat component - chemical or physical - was most limiting to aquatic communities.

Habitat Diversity

In 1982 a detailed stream habitat assessment procedure was adopted to complement fish, macroinvertebrate, water and sediment chemistry data normally collected in cooperative IEPA/IDOC basin surveys (Hite 1982). This method was predicated on the relation of habitat diversity (HD) to fish species diversity (FSD) demonstrated in several Midwest and Panama streams (Gorman and Karr 1978). This procedure was initially used in basin surveys conducted in the lower Kaskaskia, Sangamon, and Fox River Basins in 1982.

Habitat Diversity Field Methodology -- Stream habitat was measured in wadable streams along three dimensions considered important to fish. This methodology employed placement of transects along a study area with depth, velocity and substrate measured at equally spaced intervals on each transect. Location and length of the habitat study reach was identical in most cases to the IDOC fish sampling reach in cooperative basin studies. For 100 yard stream segments sampled by rotenone, transects were placed at 10 yard intervals starting from the upstream end of the study area; when available, the first transect was placed across a riffle area. This method resulted in placement of 11 equally spaced transects within the study area. Depth, velocity and substrate were recorded at equally spaced increments across each transect with increment spacing determined by mean stream width (Table 2). Water depth was measured with a USGS top-setting wading rod or fiberglass level rod to the nearest tenth of a foot (0.1 ft). Mean velocity at each transect increment was measured to 0.01 feet per second (ft/sec) with a Price AA current or pygmy meter at 0.6 total depth. Substrate or bottom type was recorded at each transect increment using appropriate substrate or bottom type codes. Habitat sampling

Table 2. Increment spacing as determined by mean stream width.

STREAM WIDTH (ft)	INCREMENT SPACING
$\bar{X}$ W $\leq$ 10	1
$\bar{X}$ W > 10 but $\leq$ 30	2
$\bar{X}$ W > 30 but $\leq$ 60	3
$\bar{X}$ W > 60 but $\leq$ 100	5
$\bar{X}$ W > 100	10

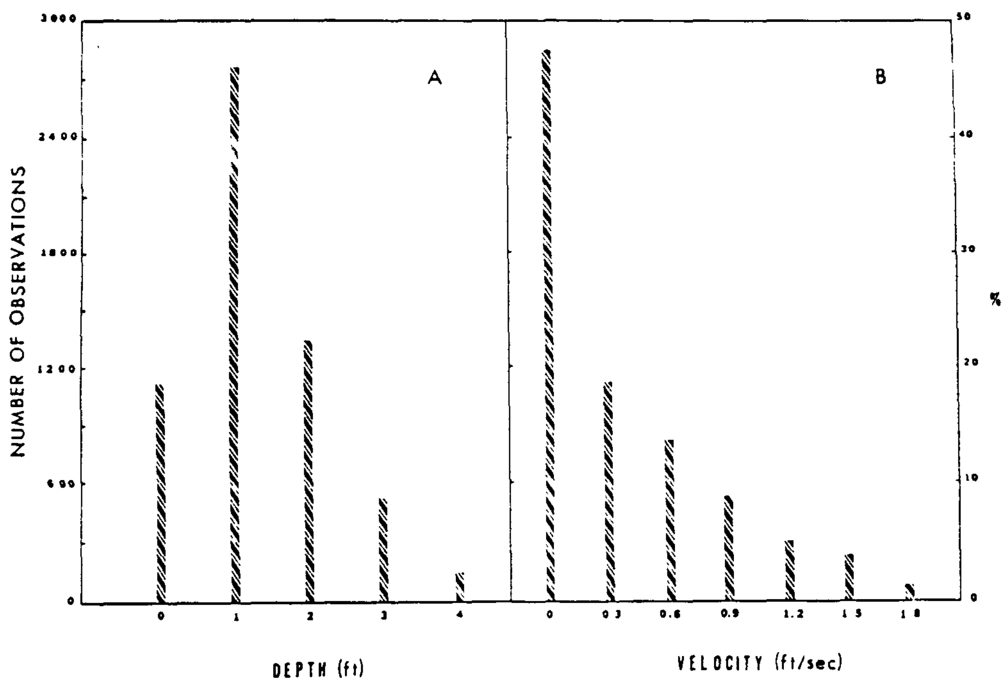

Fig. 2. Distribution of depth (A) and velocity (B) measurements at 52 lower Kaskaskia River basin sites, summer 1982.

Table 3. Instream habitat categories developed from 52 lower Kaskaskia River sites, 1982.

CATEGORY	DEPTH (ft)	VELOCITY (ft/sec)	SUBSTRATE	(INCHES	- mm)
1	0 - 0.5	-0.15 - 0.15	SILT-MUD	<0.002	<0.062
2	0.5 - 1.5	0.15 - 0.45	SAND	0.02-0.08	0.62-2
3	1.5 - 2.5	0.45 - 0.75	GRAVEL	0.08-2.5	2-64
4	2.5 - 3.5	0.75 - 1.05	RUBBLE	2.5-9.8	64-250
5	3.5 - 4.5	1.05 - 1.35	BOULDER	>9.8	250-4000
6	>4.5	1.35 - 1.65	BEDROCK		
7		>1.65	CLAYPAN		
8			PLANT DETRITUS		
9			VEGETATION		
10			LOGS		

was initiated at the right edge of water (REW) at the most downstream transect (transect 1), and proceeded in an upstream direction until HD dimensions were recorded at each increment in the 11 transect reach (Fig. 1).

In summer 1982 habitat diversity measurements were recorded at over 5900 points at 52 lower Kaskaskia fish collection sites. Study areas varied from unmodified natural stream segments, to fairly recent or older channelized areas. Stream size ranged from a few small 2nd order streams to much larger 5th or 6th order streams. Over 2700 (47%) depth measurements were within a range of 0.5 to 1.5 feet (Fig. 2). Stream velocities ranged from over 2.0 ft/sec to no detectable flow -- a common occurrence in the lower Kaskaskia Basin. Approximately 70% of all velocity measurements were less than 0.5 ft/sec. By bottom type or substrate category, over 70% of all observations consisted of silt-mud, sand or gravel.

HD Data Analysis -- Using the mainframe and discriminant analysis program available in the Statistical Analysis System (SAS 1982) package at Southern Illinois University at Carbondale, depth and velocity data were analyzed to develop categories for calculation of habitat diversity. From this analysis, six depth and seven velocity categories were identified (Table 3). With the 11 substrate categories, a possibility of 462 combinations existed for calculation of HD using the Shannon-Weiner equation. Habitat diversity values for each lower Kaskaskia River site were plotted against FSD and IBI values

Table 4. Substrate, bottom type, and other metrics used in IEPA habitat assessment procedure (modified from IEPA 1987).

CODE	SUBSTRATE	PARTICLE SIZE	OTHER METRICS
1	Silt/mud	<0.062 mm	Depth (ft)
2	Sand	0.062 - 2 mm	
3.1	Fine gravel	2 - 8 mm (0.08 - 0.3 in)	Velocity (ft/sec)
3.2	Medium gravel	8 - 16 mm (0.3 - 0.6 in)	
3.3	Coarse gravel	16 - 64 mm (0.6 - 2.5 in)	Instream Cover (%)
4.1	Small cobble	64 - 128 mm (2.5 - 5 in)	
4.2	Medium cobble	128 - 256 mm (5 - 10 in)	Pool (%)
5	Boulder	256 - 4000 mm (>10 in)	
6	Bedrock	Solid Rock	Shading (%)
	BOTTOM TYPE		
7	Claypan - compacted soil		
8	Plant detritus		
9	Vegetation		
10	Submerged logs		
11	Other ___________________		

Table 5. Habitat metrics used in stepwise multiple regression analysis.

	SUBSTRATE	
WATER QUALITY (WQI)		
DISCHARGE (CFS)	SILT-MUD	BEDROCK
MEAN DEPTH (ft)	SAND	CLAYPAN
MEAN VELOCITY (ft/sec)	GRAVEL	PLANT DETRITUS
POOL (%)	COBBLE	VEGETATION
INSTREAM COVER (%)	BOULDER	SUBMERGED LOGS
SHADING (%)		

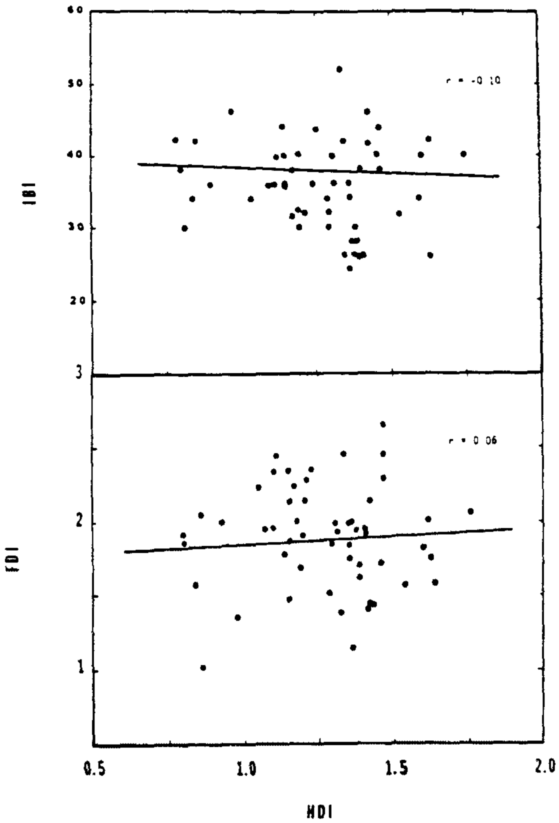

Fig. 3. Relationship of the Index of Biotic Integrity (A) and fish species (B) to habitat diversity at 52 lower Kaskaskia River basin sites, 1982.

calculated for the same location (Fig. 3). Simple linear regression analysis confirmed what wasvisually evident: no significant relationship existed between HD and FSD or IBI for the 52 lower Kaskaskia Basin sites. It was the authors' opinion that the removal of the few lower Kaskaskia Basin sites thought to be water quality limited would not have notably improved this relationship.

<u>Biotic Potential Assessment Strategy</u> -- Following evaluation of HD and the inability to demonstrate any statistical relationship between HD and FSD or IBI, alternative habitat assessment and data analysis techniques were examined. This strategy involved four basic steps: 1). development of a statewide data base consisting of sites with fishery, water quality, and habitat data collected within a similar time frame; 2). determination of sites where biotic communities were impacted or limited by water quality and elimination of sites from the data base; 3). use of statistical analysis to determine which habitat variables were most important in determining biotic integrity as measured by IBI, and; 4). development of an equation which predicted IBI from habitat metrics.

<u>Field Methods</u> -- Habitat evaluation efforts in 1983 in the upper Kaskaskia River Basin and other basin surveys utilized similar field assessment methods employed for habitat diversity but placed less emphasis on velocity measurements -- the most time consuming aspect of habitat assessment. Several other habitat metrics, however, were added to habitat surveys conducted in 1983 and subsequent years: three substrate categories, estimates of instream cover, riffle-pool development, and shading (Table 4). In general, habitat assessments conducted in conjunction with cooperative interagency basin surveys were restricted to flowing, wadeable streams and sampling was conducted with streams at base or low flow condition.

<u>Data Base Development</u> -- To develop the data base necessary to determine habitat-biotic integrity relationships, water quality, habitat, and IBI values from about

250 sites in five Illinois river basins were entered into the mainframe at Southern Illinois University at Carbondale. In addition to the metrics determined from stream habitat evaluations, stream discharge and water quality information were added. Water quality was measured by a STORET-generated index designated as WQI; this index is on a 0 to 100 scale with higher values indicating more degraded water. Water quality parameters used with this index -- temperature, dissolved oxygen, pH, total phosphorus, turbidity, conductivity, and ammonia nitrogen -- were selected on the basis of a matrix analysis which correlated water quality constituents against macroinvertebrate biotic index values (Kelly and Hite 1984).

Statistical Analysis -- Fifteen stream habitat metrics, WQI, and discharge data (Table 5) were subjected to multiple regression analysis using the PROC STEPWISE procedure in SAS (1982). When all data were included in the analysis, water quality as measured by WQI, was the most important variable affecting biotic integrity. By selectively eliminating sites from the data set on the basis of WQI values, an equation was generated that selected habitat variables in preference to water quality. It was found when only sites with WQI values less than 60 were included in the regression analysis, habitat variables became more important in explaining variance in IBI values. Following elimination of all sites exhibiting WQI values ≥ 60, 149 sites from the five river basins remained in the data base with a large number of these sites from the Kaskaskia River Basin. Remaining sites were not considered to be water quality limited; any biotic integrity perturbations now evident were attributed to be a function of physical habitat quality.

Multiple regression analyses of habitat metrics and IBI values for the 149 sites indicated four metrics appeared to exert the greatest influence on biotic integrity as measured by IBI. In order of importance, habitat variables accounting for the greatest percent variance in IBI values included: 1). Percent silt-mud ($r^2 = 0.163$), 2). Percent claypan ($r^2 = 0.216$), 3). Mean stream width ($r^2 = 0.252$), 4). Percent pool ($r^2 = 0.282$).

For biotic integrity prediction it was necessary to develop either: 1). a matrix type evaluation procedure with which applicable habitat metrics influencing IBI would be assigned arbitrary weights for stream reach classification, or 2). use the regression equation derived from the SAS PROC STEPWISE procedure. To expedite use of habitat data for aquatic life use support assessment in the 1986 IEPA 305(b) report, the later course was selected. The regression analysis yielded the following equation for prediction of biotic potential as defined by a predicted IBI value:

Predicted IBI = 40.1-(0.126*siltmud)-(0.123*claypan)+(0.0424*pool)+(0.0916*width)

Using the biotic potential equation or PIBI, predicted values can range from about 27 to 53, or from a BSC rating of a Limited Aquatic Resource (D) to a Unique Aquatic Resource (A). When applied to typical Illinois stream habitat data from 3rd to 6th order streams, most PIBI values routinely fall between 35 and 50. For 102 sites sampled in the Kaskaskia River

Basin in 1982 and 1983, having a mean stream order of 4.3, the mean predicted IBI was 40.4 (Kelly et al. 1988).

Current Biosurvey Programs

Use of macroinvertebrate, fish, and habitat data in current IEPA surface water monitoring programs falls into three general categories: 1) stream quality surveys for documentation of impacts from point source dischargers; 2) basin surveys for determination of aquatic life use support attainment and Biological Stream Characterization; and 3) Special Surveys. Point Source-Related Surveys. The majority of IEPA biosurveys are conducted to document stream conditions in the vicinity of industrial and municipal wastewater dischargers. One such program, termed Facility-Related Stream Surveys (FRSS), consists of the collection of biotic, water chemistry, stream flow and habitat quality data upstream and incrementally downstream from municipal or industrial discharges. Macroinvertebrates are utilized to assess existing stream quality and/or document degradation from the discharge. Fish are occasionally collected for contaminant analyses or for stream classification purposes. Water chemistry parameters include water temperature, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), un-ionized ammonia nitrogen, nitrate-nitrite nitrogen, and total phosphorus, and total metals. Biotic and chemical data generated from FRSS are used to assess: representativeness of Agency and discharger effluent monitoring data, stream quality impacts, the need for additional wastewater treatment, and appropriate NPDES permit limitations.

Biological Stream Characterization -- Historically, grant monies for construction or renovation of wastewater treatment facilities in Illinois have been allocated to metropolitan areas either willing to enter the grant process or able to fund their portion on construction costs. Prioritization for funding, while based on many factors, rarely had any relationship to potential aquatic life use or value of the aquatic resource to be protected. To accomplish Clean Water Act objectives and ensure that important aquatic resources are considered in the allocation of limited pollution control monies and staff resources, classification of Illinois streams was necessary.

In 1983, IEPA biologists proposed a stream classification system based on the type and condition of the fishery and macroinvertebrate community structure. This provisional classification methodology was provided to IDOC stream biologists for review and was subsequently applied to the Fox River Basin in northern Illinois in fall 1983. In Spring 1984, biologists from IEPA and IDOC met and formed the Biological Stream Characterization (BSC) Work Group to address biotic classification of Illinois streams.

The BSC Work Group developed a provisional five-tier stream classification system in 1984. This stream classification system is based largely on attributes of lotic fish communities using the Index of Biotic Integrity (Table 6). When suitable fishery data are not available for calculation of an IBI value, the site may be classified on the basis of the

Table 6. Biological Stream Characterization (BSC) criteria for the classification of Illinois streams.

RESOURCE DESCRIPTION:	UNIQUE AQUATIC RESOURCE	HIGHLY VALUED AQUATIC RESOURCE	MODERATE AQUATIC RESOURCE	LIMITED AQUATIC RESOURCE	RESTRICTED USE AQUATIC RESOURCE
BIOTIC METRIC CLASS:	A	B	C	D	E
FISHERY					
Index of Biotic Integrity (IBI) or Alternate (AIBI)	51 - 60	41 - 50	31 - 40	21 - 30	< 20
Sport Fishery Value		Good fishery for walleye, sauger, smallmouth, spotted, or largmouth bass, northern pike, white bass, crappie, catfish, rock bass, or put and take trout fishery.	Smaller species of sport fish predominate in sport catch. Bullhead/sunfish, carp fishery. Diverse forage fish community may be present.	Carp or other less desirable species support fishery. Few if any fish of other species caught.	No sport fishery. Few fish of any species.
Spawning or Nursery Value		Tributary to an "A" stream, or used as nursery by above sport fish species.	Nursery or rearing area for common sport fish. Young of year or juveniles of above species common in fish samples.	Few if any young of year or juveniles of any sport species present.	No young of year or juveniles of sport species present.
MACROINVERTEBRATES					
Macroinvertebrate Biotic Index (MBI)	N/A	N/A	N/A	$\geq$ 7.5 $\leq$ 10.0	> 10.0
Community Structure	N/A	N/A	N/A	Predominant macroinvertebrate taxa/individuals consist of facultative and/or moderate organisms. Intolerant organisms are sparse or may be absent.	Intolerant organisms absent; benthic community consists nearly all tolerant forms, or no aquatic macroinvertebrates may be present.
Species Richness	N/A	N/A	N/A	Notably lower than expected for geographic area, stream size or available habitat; usually	Restricted to few taxa, or no taxa present.

sport fishery value.
Macroinvertebrates are factored into the BSC process when fishery data are not available and are used to assign a limited or restricted BSC rating (Class D or E respectively) to stream segments greater than five miles in length. When using macroinvertebrate data for stream classification purposes, biologists may utilize MBI values and/or other community metrics such as species richness or community composition.

Aquatic Life Use Support Assessment -- In addition to use in BSC, both fishery and macroinvertebrate data are used for aquatic life use support assessments required by Section 305(b) of the Clean Water Act. In accordance with federal guidance (USEPA 1987), use support assessments are completed for each stream reach sampled in conjunction with cooperative IEPA/IDOC intensive basin surveys. The degree to which Illinois streams support designated uses is determined using a combination of biotic and abiotic data, intensive survey field observations, and professional judgment. Because it is felt that aquatic life is the best indicator of the CWA goals of fishable and swimmable waters, the use support process focuses on biotic data and Biological Stream Characterization (BSC) ratings when available. Biotic data consist of fishery and macroinvertebrate community data which are evaluated using the index of biotic integrity (Karr et al. 1986) and the IEPA Macroinvertebrate Biotic Index (MBI), respectively. Abiotic data includes water chemistry, fish tissue analysis, sediment chemistry, and physical habitat metrics.

Four levels of use support assigned to Illinois streams include: Full, Partial/Minor, Partial/Moderate, and Nonsupport (IEPA 1988). A fifth category, Full/Threatened, is occasionally used to designate waters presently considered in full support but likely to change in the future because of changing land use patterns, new point sources, or a continued decline in water quality. Where fish, stream habitat and water quality data are available for the same site, the use support category is determined using a flow chart (Fig. 4). For waters with limited data available, assessments are made with general criteria provided in a use support classification matrix (Table 7). Because the 305(b) use support assessment process uses both fish and macroinvertebrate data, use support groups closely resemble BSC categories. The general relationship of the five BSC categories to use support assessment levels and other IEPA assessment metrics and criteria is depicted in Table 8.

Classification of Fishable Waters -- Section 305(b) of the Clean Water Act also requires assessment of the degree to which CWA fishable/swimmable goals have been attained. These goals are considered separate and independent criteria from designated use assessment guidelines (USEPA 1987). USEPA has defined fishable goals for the 305(b) process as "providing a level of water quality consistent with the goal of protection and propagation of a balanced population of shellfish, fish and wildlife." In Illinois, criteria for evaluating attainment of aquatic life use has incorporated selected biotic indices or classification systems:

Table 1. Criteria and use support classification matrix for Illinois streams.

		LEVEL OF USE SUPPORT			
BASIS OF ASSESSMENT	ASSESSMENT DESCRIPTION	FULLY SUPPORTING	PARTIAL/MINOR	PARTIAL/MODERATE	NONSUPPORTING
EVALUATED	No ambient or intensive data available. Assessment based on historic data, location, similarity of area to monitored waters within geographic area or ecoregion. Assessments are predictions which have not been verified by recent monitoring data.	No point or nonpoint sources are present that could interfere with use support. Physiographic similarities of area to monitored waters or general familiarity of water or reach indicates full support.	Some water quality criteria excursions thought to exist or minor impact to aquatic life use support predicted on basis of known point or nonpoint sources or physical habitat limitations.	Moderate aquatic life impairment predicted on basis of known point or nonpoint sources or physical habitat limitations.	Severe aquatic life impairments predicted on basis of known point sources.
MONITORED					
Biosurvey Data	Fish or Macroinvertebrate community assessed by professional biologist. Assessment protocol includes evaluation of species richness, community structure and/or biotic integrity evaluation, and a comparison of biotic quality with biotic potential as measured by habitat data.	No significant modification of aquatic community structure and function (<10%). Community within expectations for stream size and physiographic region or ecoregion. Index of biotic integrity (IBI) usually >41 or within 4 points of biotic potential (PIBI) predicted by stream habitat assessment. macroinvertebrate biotic index (MBI) values usually <6.0.	Some modification of aquatic community apparent, resulting 10-25% decline in species richness, intolerant forms, number of individuals or applicable biotic index values; similar increase in number of non-sensitive forms may be evident. IBI values generally range from 31-40 or may be slightly lower than PIBI (>4 but ≤8). MBI values generally range from 6.0-7.5.	Notable deterioration of aquatic community evident; 25-50% decline in biotic community quality metrics and/or commensurate increase in number of nonsensitive individuals. IBI values typically <30, or notably lower than biotic potential (PIBI - IBI > 8 but < 14). MBI values generally range from 7.5-10.0.	Severe deterioration of aquatic community; >50% reduction in species richness, intolerant forms, number of individuals and/or applicable indices of biotic integrity. A similar increase in number of tolerant forms may be evident. Aquatic life may not be present. IBI values generally ≤23 or >14 points lower than PIBI predicted from habitat. MBI values usually >10.0.
Water Chemistry	Fixed station ambient or intensive basin water quality sampling. Assessment based on water quality index values, evaluation of raw water chemistry data and/or water quality criteria excursions. Used when biotic data are not available and/or to supplement bio-survey data.	WQI values generally <30; index values influenced primarily by phosphorus, total suspended solids (TSS) or minor DO excursions. TSS concentrations usually <25 mg/l. Pesticides or priority pollutants usually not present or detected only at trace levels. Other constituents usually within State standards.	WQI values typicaly range from from 30-50. Index values driven primarily by nutrients/TSS, or minor DO, pH excursions. TSS generally range from 25-80 mg/l. Pesticides or priority pollutants may be may be present but at low levels. Some State WQ standards may occasionally be exceeded.	WQI values usually range from 50-70. Index values may be influenced by several constituents including DO, pH, or other parameter groups. TSS generally exceed 80 mg/l. Pesticides or priority pollutants not at levels of concern when present. State WQ standards for selected constituents frequently exceeded.	WQI values generally >70; in addition to DO or pH, index values are usually influenced by several parameter groups including metals or inorganic toxicity. Extreme TSS levels (>400 mg/l) may occur. Pesticides or priority pollutants may be found at levels of concern. Water quality standards/criteria for critical aquatic life metrics routinely exceeded.
Fish Tissue	Cooperative interagency fish contaminant monitoring program; samples collected from fixed statewide network and/or from intensive studies. Tissue analysis conducted for human health implications and contaminant trend monitoring.	Organochlorine compounds in fish tissue not detected or occasionally present at trace concentrations.	Organochlorine compounds routinely detected in fish populations but contaminants not found at levels of concern.	Moderate concentrations of priority organochlorine compounds routinely detected in fish community with some species and size classes occasionally exceeding USFDA tolerance levels. Advisories for limited consumption of selected fish or sizes may be issued.	Concentrations of priority organochlorine compounds consistently found in fish community at or higher than USFDA tolerance levels. 'Consumption' advisories issued.

Hite

Table 6. SUMMARY OF USE SUPPORT ASSESSMENT CRITERIA FOR ILLINOIS STREAMS

		USE SUPPORT DESCRIPTION / CRITERIA				
	USEPA	FULL SUPPORT		PARTIAL SUPPORT MINOR	PARTIAL SUPPORT MODERATE	NON-SUPPORT
STREAM QUALITY CATEGORY	GENERAL STREAM/WATER QUALITY CONDITION	Excellent	Very Good	Fair-Good	Poor	Very Poor
STREAM QUALITY CATEGORY	IEPA/IDOC BIOLOGICAL STREAM CHARACTERIZATION (BSC)	Unique Aquatic Resource	Highly Valued Resource	Moderate Aquatic Resource	Limited Aquatic Resource	Restricted Aquatic Resource
ASSESSMENT METRIC/INDEX	FISH/Index of Biotic Integrity (IBI/AIBI)	51-60	41-50	31-40	21-30	< 20
ASSESSMENT METRIC/INDEX	BENTHOS/Macroinvertebrate Biotic Index (MBI)	< 5.0	5.0-6 0	6.0-7 5	7.5-10.0	> 10.0
ASSESSMENT METRIC/INDEX	WATER CHEMISTRY/ STORET Water Quality Index (WQI)	0-10	10-30	30-50	50-70	> 70
ASSESSMENT METRIC/INDEX	WATER CHEMISTRY/ Total Suspended Solids (TSS/mg/l)	< 10	10-25	25-80	80-400	> 400
ASSESSMENT METRIC/INDEX	STREAM HABITAT/ Potential Index of Biotic Integrity (PIBI)	51-60	41-50	31-40	< 31	
ASSESSMENT METRIC/INDEX	STREAM SEDIMENT/ IEPA Stream Sediment Classification	Nonelevated	Nonelevated -Slightly Elevated	Slightly Elevated	Elevated -Highly Elevated	Extreme

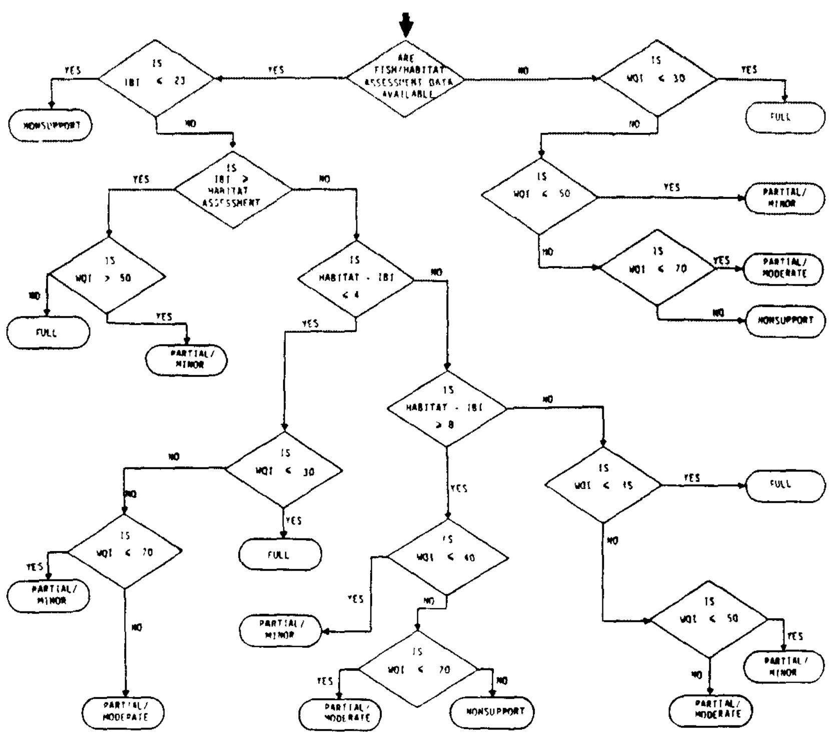

Fig. 4. Aquatic life use support assessment flow chart for fish, habitat, and water quality data.

IBI, MBI, and Biological Stream Characterization. For assessment using macroinvertebrate data, streams are considered not meeting fishable goals if MBI values are $\geq$ 10.

Special Surveys -- Special stream surveys are routinely conducted in response to catastrophic events (e.g., spills of toxic materials), mineral extraction, nonpoint source problems including agriculture and abandoned mines, and in support of enforcement proceedings. The scope and design of the survey is dependent upon the nature of the stream system and type of contaminant. In addition to use of biotic and chemistry, special surveys may utilize sediment chemistry analysis as a mechanism for screening organochlorine compound and heavy metal contaminants. The extent of stream sediment contamination is determined from an Agency sediment chemistry classification (Kelly and Hite 1984).

General Biosurvey Problem Areas

Unfortunately in many states, biosurveys and data are not utilized to the extent they should be in pollution control programs. Biosurvey problems which are evident from discussions with biologists involved with water pollution programs nationwide include: compliance and facility inspections programs measure surrogates of aquatic resource quality (i.e. effluent quality) instead of the resource itself; biotic data are frequently not considered in decisions regarding permitting activities, scheduling facility inspections, and in the awarding of construction grants; biotic data are rarely used in the decision process when siting new wastewater treatment facilities or in the relocation of existing point source discharges; bioassays appear to have been overemphasized by USEPA in recent years as the biomonitoring tool of choice. Bioassays like other types of biomonitoring, have their place in pollution control programs, but like effluent monitoring, do not measure stream biotic integrity and are useful only when representative samples are taken.

The emphasis on use of effluent data in lieu of actual stream quality data by facility inspection, compliance assurance and permitting programs occurs because: 1) the lack of biocriteria has resulted in federal mandates that require states to measure success of pollution control programs at the end of the pipe rather than by improvements in stream biotic integrity; 2) stream biocriteria have not been developed because of reliance on existing effluent and water quality standards; 3) water pollution control programs are usually managed by individuals who are technology and hardware orientated and who thus focus on facilities; 4) pollution control administrators and engineers frequently do not understand biological data; and 5) Many state water pollution control programs do not have legislative authority to address problems that are nonpoint source in nature or to manage water resources logically -- on a watershed basis.

Discussion

The macroinvertebrate, fish, and stream habitat assessment procedures presented here represent the current use of these assessment tools in biosurveys conducted by the Illinois Environmental

Protection Agency. The assessment of biotic and abiotic factors as a means of conducting lotic resource inventories, pollution control appraisals, or deriving aquatic classifications is an evolutionary process. Assessment procedures will change just as certainly as will the technology and advances in the aquatic sciences which will necessitate this change. Modification of assessment techniques will also be necessary to accommodate institutional change at the state level and never-ending change from the federal perspective.

Aquatic Biota as Environmental Indicators

Fish Community Evaluations -- Assessment of biotic integrity using fish populations will undoubtedly receive more emphasis in IEPA biosurveys in ensuing years. Fish populations integrate both chemical and physical perturbations which affect stream quality and are ideal environmental indicators from the general public perspective. Many additional advantages exist for use of this group as biological indicators (Karr, et al. 1986; Hocutt 1981). Their use in existing programs such as contaminant assessments, aquatic life use support determinations, Biological Stream Characterization, and probable use for future nonpoint source assessments assure a prominent role in Agency monitoring activities.

Benthic Macroinvertebrates -- Macroinvertebrates will continue to be the primary biotic tool used for IEPA point source related impact assessments. The advantages of using these indicator organisms to assess differences in stream quality in an "upstream-downstream" fashion and to demonstrate effectiveness of pollution control programs via pre- and post-wastewater facility construction surveys are well established (Cairns et al. 1972). The macroinvertebrate biotic index currently employed provides an adequate impairment assessment when applied to data collected from streams which receive organic wastes discharged from the typical municipal wastewater treatment facility. Utility of this index diminishes, however, when applied to data collected from streams impaired by inorganic suspended solids, toxic contaminants, and/or other abiotic perturbations. In the future, development or adoption of a multi-parameter macroinvertebrate index conceptually similar to IBI is desirable. The advantages of incorporating several attributes of community well being (e.g., taxa richness, trophic composition, etc.) into one index are obvious as interpretation of biological data must frequently be condensed down to simplistic terms or index values for understanding by water resource managers with little time or expertise to delve into complex biological data. Development and use of such an index has been initiated by the Ohio EPA (Rankin 1986) and recently advocated by USEPA as a rapid bioassessment protocol (Plafkin et al. 1987).

Stream Habitat Assessment and Classification

Habitat Diversity -- The concept that fish species diversity is ultimately related to structural and hydrological complexity in lotic ecosystems is widely accepted among practicing aquatic biologists. Failure of the habitat diversity procedure to demonstrate any significant relationship to either IBI or FSD may have been more attributable to a data set restricted geographically than error in theory. The relative homogeneity (i.e., lack of diversity) of stream habitat in the largely agricultural lower Kaskaskia River Basin may have been in part responsible for lack of any relationship. A true test of this relationship would be better assessed by a much larger data base of widely differing fish communities and habitat types -- something that was lacking in the data set used.

Habitat Assessment -- Evaluation of stream habitat quality will continue to be an integral component of IEPA biosurveys. Prediction of biotic potential (PIBI) by use of a single multiple regression equation is not without problems. The present predictive equation was essentially based on the relationship of the Index of Biotic Integrity to physical habitat variables in third to fifth order central Illinois streams -- primarily the Kaskaskia River Basin. This central Illinois region, designated as the Central Corn Belt Plains Ecoregion (Omernik 1987), encompasses about 75% of the State; because of general physiographic similarities in this ecoregion, use of the PIBI equation may be applicable to many smaller streams in this area. Caution is suggested, however, in use of this equation for predicting IBI in physiographically dissimilar regions in Illinois, or elsewhere. Ultimately, continued use of a predictive equation for use support assessment or Biological Stream Characterization will require a specific equation be developed for each ecoregion, physiographic region, or river basin in Illinois where this procedure is to be used.

An array of habitat evaluation and data interpretation techniques have been developed for both warmwater and coldwater lotic systems, although certainly emphasis has been placed on the latter. The habitat and data assessment procedures detailed here are by no means considered state of the art or the best assessment techniques. The need for uniform habitat assessment techniques for similar geographic areas and program objectives is evident and has prompted formation of stream habitat assessment standardization committees by the American Fisheries Society at the national and more recently division level. These efforts have been proceeded by publication of proceedings from at least two major habitat evaluation-related symposia (Armantrout 1981; USF&W 1977) and by significant efforts at habitat quantification for aquatic life instream flow needs (Bovee 1982). Elaborate procedures for documentation of habitat requirements at the species level (USF&W 1980) have also been developed as have excellent and detailed methods for the assessment of stream habitat metrics (Platts et al. 1983).

Biological Stream Characterization

Historically, classification of streams in this country has been based on a multitude of biotic and abiotic variables. In Illinois, fish community characteristics have been used to rate the quality of major Illinois river basins (Smith 1971). Recent use of the Biological Stream Characterization (BSC) system by the Illinois

Environmental Protection Agency and Department of Conservation has emphasized biotic integrity measured by IBI and/or the value of the sport fishery resource. BSC is intended to serve the somewhat different objectives of two state agencies: one delegated authority for regulation of water quality (IEPA) and the other, management of aquatic life in Illinois (IDOC). It is therefore not surprising that BSC does not totally address the needs of either agency as well as a classification system dedicated to a single agency's specific needs. Because many important sport fishes in Illinois -- notably the centrarchids and ictalurids -- are generally considered fairly tolerant fishes, BSC ratings predicated on sport fishery values may not accurately reflect ambient water quality or habitat quality. In the future it will be necessary to evaluate present IBI numerical ranges used for BSC ratings and their relationship to water quality; and finally, it may be necessary to incorporate other stream quality metrics into BSC such as water and habitat quality before the full potential of this classification procedure is realized and ultimately used by Illinois water resource managers.

Literature Cited

Armantrout, N.B.(ed.) 1981. Acquisition and utilization of aquatic habitat inventory information. Proceedings of a Symposium held 28-30 October. Portland, Oregon.

Bertrand, B.A. 1985. Draft ratings for streams. Biological Stream Characterization Work Group Memorandum. Illinois Department of Conservation. Springfield, Illinois.

Bickers, C.A., M.H. Kelly, R.L. Hite, and J.M. Leuesque. 1988. User's guide to IBI-AIBI: version 2.01. A BASIC program for computing the Index of Biotic Integrity with the IBM PC. Illinois Environmental Protection Agency. Springfield, Illinois.

Bovee, K.D. 1982. A guide to habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper No. 12. FWS/OBS-82/26.

Cairns, J. Jr., K.L. Dickson, and A. Hendricks. 1972. Pre- and post-construction surveys. Industrial Water Engineering 9(2): 33-35.

Conlin, M. 1976. Stream channelization in Illinois - 1976 update. Illinois Department of Conservation. Springfield, Illinois. Unpublished manuscript.

Gorman, O.T. and J.R. Karr. 1978. Habitat structure and stream fish communities. Ecology 57(3): 507-515.

Hilsenhoff, W.L. 1977. Use of arthropods to evaluate water quality of streams. Wisconsin Department of Natural Resources Technical Bulletin 100. Madison, Wisconsin.

Hilsenhoff, W.L. 1982. Using a biotic index to evaluate water quality in streams. Wisconsin Department of Natural Resources Technical Bulletin 132. Madison, Wisconsin.

Hite, R.L. 1982. Measurement of stream habitat diversity. Illinois Environmental Protection Agency.

Springfield, Illinois. Unpublished manuscript.

Hite, R.L. and M.M. King. 1976. Biological investigation of the Crab Orchard Creek basin: summer 1975. Illinois Environmental Protection Agency. Springfield, Illinois.

Hite, R.L., M.M. King, M.R. Matson, and C.A. Bickers. 1988. An intensive survey of the Sugar Creek Basin, Crawford County, Illinois. Illinois Environmental Protections Agency Report: IEPA/WPC/88-030. Springfield, Illinois.

Hocutt, C.H. 1981. Fish as indicators of biological integrity. Fisheries 6(6): 28-31.

Illinois Environmental Protection Agency. 1987. Quality assurance and field methods manual, Division of Water Pollution Control, Section C: Macroinvertebrate monitoring. Springfield, Illinois.

Illinois Environmental Protection Agency. 1988. Illinois Water Quality Report 1986-1987: IEPA/WPC/88-002. Division of Water Pollution Control, Springfield, Illinois

Isom, B.G. 1978. Benthic macroinvertebrates. In Methods for the assessment and prediction of mineral mining impacts on aquatic communities: a review and analysis. US Fish & Wildlife Service: FWS/OBS-78/30.

Karr. J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6(6): 21-27.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biotic integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5. Champaign, Illinois.

Kelly, M.H. 1986. Users guide to BIBI: version 1.5. A BASIC program for computing the Index of Biotic Integrity. Illinois Environmental Protection Agency. Springfield, Illinois.

Kelly, M.H. and R.L. Hite. 1984. Evaluation of Illinois stream sediment data 1974 - 1980. Illinois Environmental Protection Agency Report: IEPA/84-004. Springfield, Illinois.

Kelly, M.H. and R.L. Hite. 1984. An evaluation of empirical correlations between the macroinvertebrate biotic index (MBI) and the STORET water quality index (WQI). Illinois Environmental Protection Agency. Springfield, Illinois.

Kelly, M.H., R.L. Hite, and C.A. Bickers. 1988. An intensive survey of the Kaskaskia River Basin 1982-1983. Illinois Environmental Protection Agency. Springfield, Illinois.

Mauck, W.L. and L.E. Olson. 1977. Polychlorinated biphenyls in adult mayflies (Hexagena bilineata) from the upper Mississippi River. Bulletin of Environmental Contamination and Toxicology 17: 387-390.

Mills, K.H. and D.W. Schindler. 1986. Biological indicators of lake acidification. Water, Air, and Soil Pollution 30: 779-789.

Omernik, J.M. 1987. Ecoregions of the conterminous United States.

Annals of the Association of American Geographers 77: 118-125.

Pflieger, W.L. 1975. The fishes of Missouri. Missouri Department of Conservation. Jefferson City, Missouri.

Plafkin, J.L., M.T. Barbour, K.D. Porter, and S.K. Gross. 1987. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates. USEPA, Washington, D.C.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. US Department of Agriculture, Forest Service, Intermountain Forest and Range Experimental Station. Gen. Tech. Rep. INT-138, Ogden, Utah.

Resh, V.H. and J.D. Unzicker. 1975. Water quality monitoring and aquatic organisms: the importance of species identification. Journal Water Pollution Control 47: 9-19.

Schaeffer, D.J., W.H. Ettinger, W.J. Tucker, and H.W. Kerster. 1985. Evaluation of a community-based index using benthic indicator-organisms for classifying stream quality. Journal Water Pollution Control 57: 167-171.

Shiffman, R.H. 1953. A method of cataloging bottom organisms in respect to their pollutional tolerance. Illinois Department of Public Health, Springfield, Illinois.

Smith, P.W. 1971. Illinois streams: a classification on their fishes and an analysis of factors responsible for disappearance of native species. Illinois Natural History Survey, Biological Notes 76. Champaign, Illinois.

Smith, P.W. 1979. The Fishes of Illinois. University of Illinois Press. Urbana, Illinois.

Stauffer, J.R. Jr., K.L. Dickson, J. Cairns Jr., and D.S. Cherry. 1976. The potential and realized influence of temperature on the distribution of fishes in the New River, Glen Lyn, Virginia. Wildlife Monographs No. 50.

Statistical Analysis System Institute. 1982. SAS user's guide: statistics. SAS Institute Inc. Gary, North Carolina.

Tucker, W.J. 1961. North Fork of the Vermilion River survey, Danville and Hoopeston. Illinois Department of Public Health, Springfield, Il.

U.S. Environmental Protection Agency. 1982. Water quality standards handbook. Draft. USEPA, Office of Water Regulation and Standards. Washington, D.C.

U.S. Environmental Protection Agency. 1983. Technical support manual: waterbody surveys and assessments for conducting use attainability analyses. USEPA, Office of Water Regulations and Standards. Washington, D.C.

U.S. Environmental Protection Agency. 1987. Guidelines for the preparation of the 1988 state water quality assessment (305(b) report. USEPA, Monitoring and Data Support Division. Washington, D.C.

U.S. Fish and Wildlife Service. 1977. Classification, inventory, and analysis of fish and wildlife habitat. Proceedings of a National

Symposium. FWS/OBS-78/76. Washington, D.C.

U.S. Fish and Wildlife Service. 1980. Habitat evaluation procedures (HEP). USFWS, Division of Ecological Services, ESM. Washington, D.C.

Weber, C.H. (Ed.) 1974. Biological field and laboratory methods for measuring the quality of surface water and effluents. USEPA, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

Winner, R.W., M.W. Boesel, and M.P. Farrell. 1980. Insect community structure as an index of heavy-metal pollution in lotic ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 37: 647-655.

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY MACROINVERTEBRATE TOLERANCE LIST

MACROINVERTEBRATE	TOLERANCE VALUE
PLATYHELMINTHES	
TURBELLARIA	6
ANNELIDA	
OLIGOCHAETA	10
HIRUDINEA	8
Rhynchobdellida	
Glossiphoniidae	8
Piscicolidae	7
Gnathobdellida	
Hirudinidae	7
Pharyngobdellida	
Erpobdellidae	8
ARTHROPODA	
CRUSTACEA	
ISOPODA	
Asellidae	6
Caecidotea	6
brevicauda	6
intermedia	6
Lirceus	4
AMPHIPODA	
Hyalellidae	
Hyalella	
azteca	5
Gammaridae	
Bactrurus	1
Crangonyx	4
Gammarus	3
DECAPODA	
Cambaridae	5
Palaemonidae	
Palaemonetes	4
INSECTA	
EPHEMEROPTERA	
Siphlonuridae	
Ameletus	0
Siphlonurus	2
Oligoneuriidae	
Isonychia	3
Metretopodidae	
Siphloplecton	2
Baetidae	
Baetis	4
brunneicolor	4
flavistriga	4
frondalis	4
intercalaris	7
longipalpus	6
macdunnoughi	4
propinquus	4
pygmaeus	4
tricaudatus	1
Callibaetis	4
fluctuans	4
Centroptilum	2
Cloeon	3
Pseudocloeon	4
dubium	4
parvulum	4
punctiventris	4

MACROINVERTEBRATE	TOLERANCE VALUE
Heptageniidae	
Arthroplea	3
Epeorus	1
vitreus	0
Heptagenia	3
diabasia	4
flavescens	2
hebe	3
lucidipennis	3
maculipennis	3
marginalis	1
perfida	1
pulla	0
Rhithrogena	0
Stenacron	4
candidum	1
gildersleevei	1
interpunctatum	4
minnetonka	4
Stenonema	4
annexum	4
ares	3
exiguum	5
femoratum	7
integrum	4
luteum	1
mediopunctatum	2
modestum	3
nepotellum	5
pudicum	2
pulchellum	3
quinquespinum	5
rubromaculatum	2
scitulum	1
terminatum	4
vicarium	3
Ephemerellidae	
Attenella	2
Danella	2
Drunella	1
Ephemerella	2
Eurylophella	4
Seratella	1
Tricorythidae	
Tricorythodes	5
Caenidae	
Brachycercus	3
Caenis	6
Baetiscidae	
Baetisca	3
Leptophlebiidae	
Choroterpes	2
Habrophlebiodes	2
americana	2
Leptophlebia	3
Paraleptophlebia	2
Potamanthidae	
Potamanthus	4
Ephemeridae	
Ephemera	3
simulans	3

MACROINVERTEBRATE	TOLERANCE VALUE
Hexagenia	6
limbata	5
munda	7
Palingeniidae	
Pentagenia	4
vittigera	4
Polymitarcyidae	
Ephoron	2
Tortopus	4
ODONATA	
ANISOPTERA	
Cordulegasteridae	
Cordulegaster	2
Gomphidae	
Dromogomphus	4
Gomphus	7
Hagenius	3
Lanthus	6
Ophiogomphus	2
Progomphus	5
Aeshnidae	
Aeshna	4
Anax	5
Basiaeschna	2
Boyeria	3
Epiaeschna	1
Nasiaeschna	2
Macromiidae	
Didymops	4
Macromia	3
Corduliidae	
Cordulia	2
Epitheca	4
Helocordulia	2
Neurocordulia	3
Somatochlora	1
Libellulidae	
Celithemis	2
Erythemis	5
Erythrodiplax	5
Libellula	8
Pachydiplax	8
Pantala	7
Perithemis	4
Plathemis	3
Sympetrum	4
Tramea	4
ZYGOPTERA	
Calopterygidae	
Calopteryx	4
Hetaerina	3
Lestidae	
Archilestes	1
Lestes	6
Coenagrionidae	
Amphiagrion	5
Argia	5
moesta	5
tibialis	5
Enallagma	6
signatum	6
Ischnura	6
Nehalennia	7

MACROINVERTEBRATE	TOLERANCE VALUE
PLECOPTERA	
Pteronarcyidae	
Pteronarcys	2
Taeniopterygidae	
Taeniopteryx	2
Nemouridae	
Nemoura	1
Leuctridae	
Leuctra	1
Capniidae	
Allocapnia	2
Capnia	1
Perlidae	
Acroneuria	1
Atoperla	1
Neoperla	1
Perlesta	4
placida	4
Perlinella	2
Perlodidae	
Hydroperla	1
Isoperla	2
Chloroperlidae	
Chloroperla	3
MEGALOPTERA	
Sialidae	
Sialis	4
Corydalidae	
Chauliodes	4
Corydalus	3
Nigronia	2
NEUROPTERA	
Sisyridae	1
TRICHOPTERA	
Hydropsychidae	
Cheumatopsyche	6
Diplectrona	2
Hydropsyche	5
arinale	5
betteni	5
bidens	5
cuanis	5
frisoni	5
orris	4
phalerata	2
placoda	4
simulans	5
Macronema	2
Potamyia	4
Symphitopsyche	4
Philopotamidae	
Chimarra	3
Dolophilodes	0
Polycentropodidae	
Cyrnellus	5
Neureclipsis	3
Nyctiophylax	1
Polycentropus	3
Psychomyiidae	
Psychomyia	2
Glossosomatidae	
Agapetus	2
Protoptila	1

MACROINVERTEBRATE	TOLERANCE VALUE
Hydroptilidae	
Agraylea	2
Hydroptila	2
Ithytrichia	1
Leucotrichia	3
Mayatrichia	1
Neotrichia	4
Ochrotrichia	4
Orthotrichia	1
Oxyethira	2
Rhyacophilidae	
Rhyacophila	1
Brachycentridae	
Brachycentrus	1
Lepidostomatidae	
Lepidostoma	3
Limnephilidae	
Hydatophylax	2
Limnephilus	3
Neophylax	3
Platycentropus	3
Pycnopsyche	3
Phryganeidae	
Agrypnia	3
Banksiola	2
Phryganea	3
Ptilostomis	3
Helicopsychidae	
Helicopsyche	2
Leptoceridae	
Ceraclea	3
Leptocerus	3
Mystacides	2
Nectopsyche	3
Oecetis	5
Triaenodes	3
COLEOPTERA	
Gyrinidae (larvae only)	
Dineutus	4
Gyrinus	4
Psephenidae (larvae only)	4
Psephenus	4
herricki	4
Eubriidae	4
Ectopria	4
thoracica	4
Dryopidae	4
Helichus	4
lithophilus	4
Helodidae (larvae only)	7
Elmidae	
Ancyronyx	2
variegatus	2
Dubiraphia	5
bivittata	2
quadrinotata	7
vittata	7
Macronychus	2
glabratus	2
Microcylloepus	2
Optioservus	4
ovalis	4
Stenelmis	7
crenata	7
vittipennis	6

MACROINVERTEBRATE	TOLERANCE VALUE
DIPTERA	
Blephariceridae	0
Tipulidae	4
Antocha	5
Dicranota	4
Eriocera	7
Helius	5
Hesperoconopa	2
Hexatoma	4
Limnophila	4
Limonia	3
Liriope	7
Pedicia	4
Pilaria	4
Polymeda	2
Pseudolimnophila	2
Tipula	4
Chaoboridae	8
Culicidae	8
Aedes	8
Anopheles	6
Culex	8
Psychodidae	11
Ceratopogonidae	5
Atrichopogon	2
Palpomyia	6
Simuliidae	
Cnephia	4
Prosimulium	2
Simulium	6
clarkei	4
corbis	0
decorum	4
jenningsi	4
luggeri	2
meridionale	1
tuberosum	4
venustum	6
verecundum	6
vittatum	8
Chironomidae	
Tanypodinae	
Ablabesmyia	6
mallochi	6
parajanta	6
peleensis	6
Clinotanypus	6
pinguis	6
Coelotanypus	4
Labrundinia	4
Larsia	6
Macropelopia	7
Natarsia	6
Pentaneura	3
Procladius	8
Psectrotanypus	8
Tanypus	8
Thienemannimyia group	6
Zavrelimyia	8
Diamesinae	
Diamesa	4
Pseudodiamesa	1

MACROINVERTEBRATE	TOLERANCE VALUE
Orthocladiinae	
Cardiocladius	6
Chaetocladius	6
Corynoneura	2
Cricotopus	8
bicinctus	10
trifasciatus	6
Eukiefferiella	4
Hydrobaenus	2
Nanocladius	3
Orthocladius	4
Parametriocnemus	4
Prodiamesa	3
Psectrocladius	5
Rheocricotopus	6
Thienemanniella	2
xena	2
Chironominae	
Chironomus	11
attenuatus	10
riparius	11
Cryptochironomus	8
Cryptotendipes	6
Dicrotendipes	6
modestus	6
neomodestus	6
nervosus	6
Einfeldia	10
Endochironomus	6
Glyptotendipes	10
Harnischia	6
Kiefferulus	7
Microtendipes	6
Parachironomus	8
Paracladopelma	4
Paralauterborniella	6
Paratendipes	3
Phaenopsectra	4
Polypedilum	6
fallax	6
halterale	4
illinoense	5
scalaenum	6
Pseudochironomus	5
Stenochironomus	3
Stictochironomus	5
Tribelos	5
Xenochironomus	4
Tanytarsini	
Cladotanytarsus	7
Micropsectra	4
Rheotanytarsus	6
Tanytarsus	7
Ptychopteridae	8
Tabanidae	7
Chrysops	7
Tabanus	7
Dolichopodidae	5
Empididae	6
Hemerodromia	6

MACROINVERTEBRATE	TOLERANCE VALUE
Syrphidae	11
Ephydridae	8
Sciomyzidae	10
Muscidae	8
Athericidae	
Atherix	4
MOLLUSCA	
GASTROPODA	
Viviparidae	
Campeloma	7
Lioplax	7
Viviparus	1
Valvatidae	
Valvata	2
Bulimidae	
Amnicola	4
Pleuroceridae	
Goniobasis	5
Pleurocera	7
Physidae	
Aplexa	7
Physa	9
Lymnaeidae	
Lymnaea	7
Stagnicola	7
Planorbidae	
Gyraulus	6
Helisoma	7
Planorbula	7
Ancylidae	
Ferrissia	7
PELECYPODA	
Unionidae	
Actinonaias	
carinata	1
Alasmidonta	
marginata	1
triangulata	0
Anodonta	3
Carunculina	7
Elliptio	2
Fusconaia	1
Lampsilis	1
Ligumia	1
Margaritifera	1
Micromya	1
Obliquaria	1
Proptera	1
Strophitus	4
Tritogonia	1
Truncilla	1
Utterbackia	1
Sphaeriidae	
Musculium	5
Pisidium	5
Sphaerium	5
Cyrenidae	
Corbicula	4

Appendix B. **IBI SUMMARY TABLE**

STREAM NAME: Beaver Creek
STATION CODE: OIB-02
STATION DESCRIPTION:
COUNTY: Clinton T: 3N R: 3W
1/4 SECT: SW27
COLLECTOR(S): IDOC
AIBI COMPUTED BY: R.L. Hite
METHOD: RO
STREAM ORDER = 5
DATE OF COLLECTION: 6-30-82
DATE OF CALCULATION: 1-17-89
AREA SAMPLED = .183 ACRES
UNIT OF EFFORT:
Additional information:

Number of native species = 16
Species metric factor = 3
Number of sucker species = 2
Sucker metric factor = 3
Number of sunfish species = 2
Sunfish metric factor = 3
Number of darter species = 1
Darter metric factor = 1
Number of intolerant species = 1
Intolerant metric factor = 1
Prop.(%) of Green sunfish = 29.78723
Green metric factor = 1
Prop.(%) of Hybrids = 0
Hybrid metric factor = 5
Prop.(%) of omnivores = 6.808511
Omnivore metric factor = 5
Prop.(%) of insect. cypr. = 5.957447
Ins. cypr. metric factor = 1
Prop.(%) of carnivores = 3.829787
Carnivore metric factor = 3
# of fish/0.1 ac = 128.4153
Condition factor = 2.454546
Abundance factor (based on sampling method) = 1
Total abundance = 235
Total number of species = 16

The AIBI for this site is: 29.45455

SPECIES ABUNDANCE TABLE

	Common name	Scientific name	Abundance
1	grass pickerel	Esox americanus	9
2	carp	Cyprinus carpio	4
3	golden shiner	Notemigonus crysoleucas	12
4	red shiner	Notropis lutrensis	1
5	sand shiner	Notropis stramineus	1
6	redfin shiner	Notropis umbratilis	12
7	white sucker	Catostomas commersoni	2
8	bigmouth buffalo	Ictiobus cyprinellus	1
9	black bullhead	Ictalurus melas	3
10	yellow bullhead	Ictalurus natalis	19
11	tadpole madtom	Noturus gyrinus	11
12	pirate perch	Aphredoderus sayanus	76
13	blackstripe topminnow	Fundulus notatus	11
14	green sunfish	Lepomis cyanellus	70
15	longear sunfish	Lepomis megalotis	1
16	slough darter	Etheostoma gracile	2